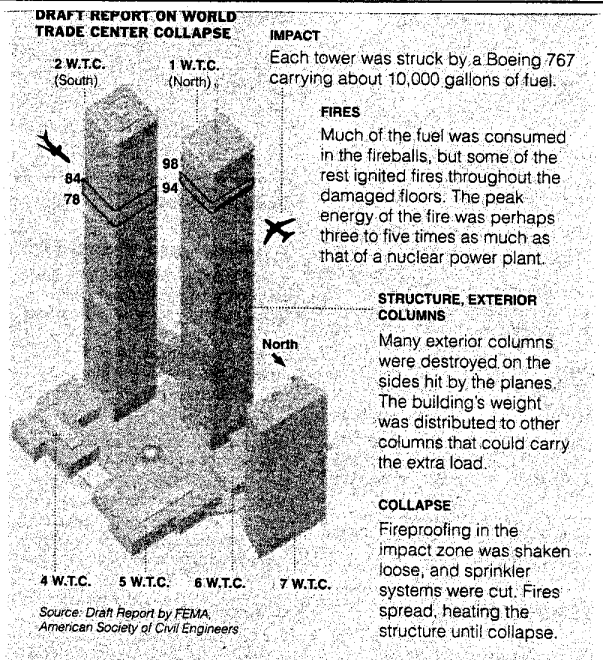


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The New York Times; Illustration by John Papasian

Towers Withstood Impact, But Fell to Fire, Report Says

By JAMES GLANZ and ERIC LIPTON

Fireproofing, sprinkler systems and the water supply for hoses all largely failed in the twin towers on Sept. 11 in the face of a blaze so intense that it drove temperatures as high as 2,000 degrees and generated heat equivalent to the energy output of a nuclear power plant, a federal report on how the towers fell has concluded.

The fire, combined with these failures, brought down the towers even after they had shown surprising and lifesaving resiliency to massive structural damage caused by the impact of two hijacked airliners, the report says.

The report's findings detail for the first time the horrific series of events that led to the collapse of two of the world's tallest buildings. They are contained in a draft of a report commissioned by the Federal Emergency Management Agency and the American Society of Civil Engineers.

The draft describes a structure that showed both remarkable strength and critical weaknesses. As was obvious to television viewers worldwide, the towers sustained the initial impact of the planes and were able to redistribute loads away from damaged columns so well that they could probably have remained standing indefinitely if not for the fires, an earthquake or a windstorm, the report said. Team members are still debating the delicate question of whether the tremendous fires could have brought the towers down on their own.

"The ability of the two towers to withstand aircraft impact without immediate collapse was a direct function of their design and construction characteristics, as was the vul-

nerability of the two towers to collapse as a result of the combined effects of the impacts and ensuing fires," the report concludes.

The report, a copy of which was obtained by The New York Times, is not due to be released officially until late April or early May. It provides documentary evidence that simultaneously supports and rejects many of the theories about what happened to the towers on Sept. 11.

What is already clear is that the jet fuel played a role somewhat different, though still critical, than some experts had speculated. After the planes slammed into the towers,

Continued on Page A14

Death Penalty Sought

The Justice Department said that it would seek the death penalty for Zacarias Moussaoui, the only person arrested in the Sept. 11 attacks. He is charged with conspiring with Osama bin Laden and the Qaeda terrorist network.

Article, Page A14.

A14 YNE

THE NEW YORK TIMES, FRIDAY, MARCH 29, 2002

A NATION CHALLENGED: Investigations, Scientific and Criminal

THE TRADE CENTER

Federal Report Says Fire's Intensity Led to the Fall of the Twin Towers

Continued From Page A1

the fireballs that burst over Lower Manhattan consumed perhaps a third of the 10,000 gallons of fuel on board each plane, for example, but did little structural damage themselves, the report says.

Like a giant well of lighter fluid, though, the remaining fuel burned within minutes, setting ablaze furniture, computers, paper files and the planes' cargo over multiple floors and igniting the catastrophic inferno that brought the towers down.

Under normal circumstances, fire suppression systems are designed to allow a high-rise blaze to burn itself out before the building collapses. But the report concludes that there were across-the-board failures in the towers' fire suppression systems, raising disturbing questions about the safety and integrity of other tall buildings in out-of-control fires. But the ultimate significance of those failures is extremely difficult to gauge, the report says, because of the extraordinary circumstances of the attack.

In fact, besides just setting the fires, the impact of the jets may have jarred loose the light, fluffy fireproofing that had been sprayed on steel columns, and flying debris almost certainly sliced through the vertical pipes that supplied water for the hoses and sprinklers.

Because of those uncertainties, the report says, building codes and engineering practices should be studied extensively to consider changes, a step the federal government is already planning, with a \$16 million two-year inquiry by the National Institute of Standards and Technology now getting under way. The final version of the FEMA report may recommend specific changes in building codes and standards.

The report is also significant for what it does not include. With the exception of a few contorted steel beams from 5 World Trade Center, a nine-story office building that also burned and suffered localized collapses because the beams failed where they were bolted together, little evidence collected from the piles of debris contributed in a meaningful way to the report's conclusions.

That absence could intensify criticism of an early decision by the city to recycle steel from the trade center rather than make it immediately available for collection and analysis by the research team. About 60 pieces of trade center steel are being sent to the technology institute for the investigation, so future analysis could provide additional answers.

The draft report also does not contain any discussion of what could become a contentious new issue in attempts to explain why the south tower, though struck after the north tower, fell first. That question involves a program, started after the 1993 bombing of the towers, to increase the thickness of the fireproofing on the lightweight steel joists that held up the floors.

AT THE TIME OF THE ATTACK, 10 FLOORS

on the north tower and 13 floors in the south tower had been upgraded, by increasing the thickness of the fireproofing from three-quarters of an inch to an inch and a half. As it happened, the planes hit floors in the north tower whose fireproofing thickness had already been increased, and floors in the south that had not been upgraded — with one exception, the 78th floor.

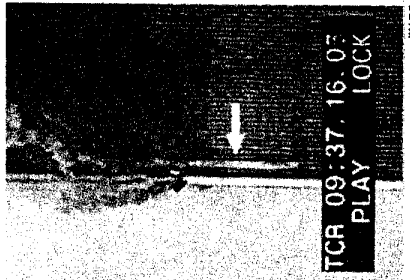
Team members are carefully debating what role that difference may have played in the length of time the towers stood after impact: 56 minutes, 10 seconds for the south tower and 102 minutes, 5 seconds for the north. But there are several other possible explanations. The plane that struck the south tower was moving at least 100 miles an hour faster than the other one, heightening the energy upon impact. And it hit 10 floors lower, resulting in far more weight from above bearing down on the damaged area.

Whatever its thickness, much of the fireproofing was probably dislodged by the impact of the planes, the investigators concluded. One official, knowledgeable about the fireproofing said the woolly, mineral-based material could be brushed away with the wipe of a finger.

Stripped of its fireproofing, a steel column heats up much more quickly in a fire. The hotter the steel, the less it is able to support loads, as it eventually becomes as soft as licorice. Investigators believe that the structural steel was also greatly imperiled because the sprinklers and standpipes supplying water for firefighting were almost certainly disabled, their supply pipes cut by debris sent flying in the initial crash.

The sprinklers were installed by about 1990 and tanks were stored as high as the 110th floor of the buildings. Witnesses below the areas of impact, and therefore below the primary fires, described water cascading down the stairwells where pipes from those tanks ran. The hoses that firefighters carried on their backs up the same stairwells would therefore have been largely useless, since the standpipes used the same supplies.

The report cites the tight clustering of the exit stairways, three per tower, as a factor that may have made it easier to cause damage to all of them with one blow. These exit



Arrow indicates molten metal, possibly aluminum from the airplane, coming from the south tower just minutes before it collapsed.

stairwells also had relatively lightweight gypsum board sheathing, providing little armor. Partly for these reasons, thousands of people above the floors of impact were trapped.

Most of the tenants in the floors below impact, to the credit of the building and the emergency lighting in the stairwells, escaped. More than 400 firefighters, police officers and other rescue personnel and dozens of tenants who stayed behind during the evacuation were also killed when the buildings finally collapsed. An estimated 2,830 people are considered dead or missing in the collapse.

Against the Manhattan skyline, gleaming towers looked nearly identical, except for the television tower atop the north tower. But the inquiry found that the forces that toppled them had distinct differences.

Their basic structures before the

attacks were extremely similar, even if they were not quite perfect twins. Each tower was supported against the downward force of gravity by a tightly arranged matrix of columns at its core and another pallade of columns, spaced just 40 inches apart, around its exterior.

The core and perimeter columns were connected by lightweight, web-like floor supports called trusses at each floor. The trusses held up corrugated metal decks on which the concrete floors were poured. The same trusses provided lateral support for all the vertical columns, preventing them from buckling under the tremendous force of gravity.

Wide plates called spandrels tied the exterior steel columns together, creating a rigid surface that could resist hurricane-force winds.

These structural elements would become fateful as the jets plowed into the north tower at 8:46 a.m. and the south tower at seconds before 9:03 a.m.

The report — assembled with data collected at ground zero, in scrapyards, in laboratories, by analyzing more than 100 hours of videotape and by talking to witnesses — turned up the greatest amount of detail on the south tower attack.

The United Airlines jet, its wings slightly canted, angled into the south facade of the south tower, slicing through about 30 of the 59 exterior columns on that face. The immediate devastation, probably including unseen destruction to the steel core, stretched from the 78th to the 84th floors.

The impact of the plane, which had been traveling as fast as 586 miles an hour, was so great that it gathered office material like a snowplow and apparently forced it toward the northeast corner of the building. Parts of the plane came to rest there and others punctured the far wall, soaring as far as six blocks to the

north before hitting the ground near the intersection of Murray and Church Streets.

A fuel-fed fireball emerged from three sides of the tower and consumed roughly one-third of the estimated 10,000 gallons on the plane. Some of the rest flowed down the face of the building and into elevator shafts and stairwells. What remained burned ferociously, setting acres of office space afire as well as the plane's cargo.

The incredible energy generated by this blaze was estimated peak to be three to five gigawatts at its peak. A typical nuclear power plant generates about one gigawatt. All of that energy was converted to deadly heat that began weakening the steel

been shoved by the plane, the fire burned so hot that a stream of molten metal began to pour over the side like a flaming waterfall.

The apparent source of this waterfall: molten aluminum from the jet's wings and fuselage, which had also piled up in that corner. Within minutes, portions of the 80th floor began to give way, as evidenced by horizontal lines of dust blowing out the side of the building. Seconds later, near the heavily damaged southeasterly portion of this same floor, close to where the aircraft had entered, exterior columns began to buckle.

Fifty-six minutes and 10 seconds after it was hit, the top of the south tower tilted horribly to the east and then to the south, and initiated the collapse of the entire tower, floor upon floor.

Unfolding at a slower pace, the disaster at the north tower will require study before it can be explained in such detail. The plane entered the north tower between the 94th and 98th floors, the report says, destroying about 35 columns on its north face and wreaking indeterminable but probably substantial damage to the core.

The building stood for more than an hour and a half. Videos of the north tower's collapse appear to show that its television antenna began to drop a fraction of a second before the rest of the building. The observations suggest that the building's steel core somehow gave way first, pulling down the rest of the tower with it.

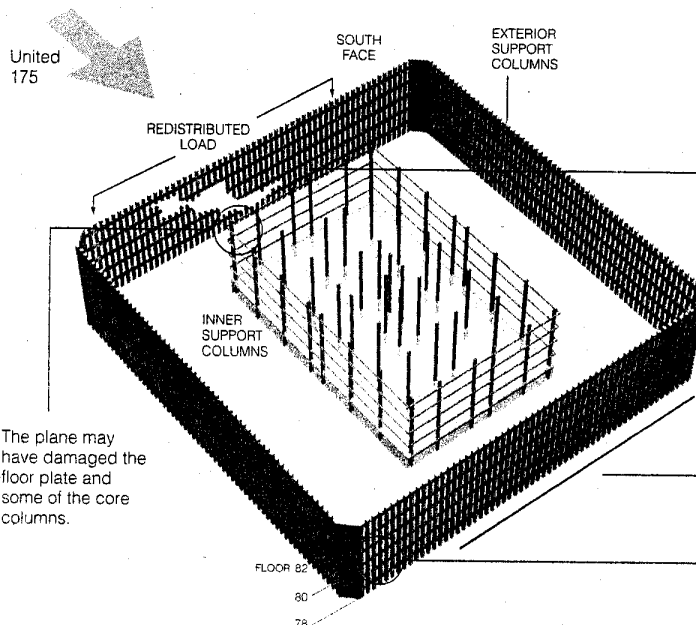
For a few unreal moments, after the north tower had plummeted to the ground, a giant spearlike fragment of the facade remained standing, as if defiantly, looming above the lesser skyscrapers around it. Then the last shard of the tower fell, leaving behind only its arched, cathedral-like base and a narrow trail of smoke to trace its path to the ground.

Remarkable strength, and critical weaknesses.

But the tower did not fall immediately. Preliminary calculations by the engineering team have revealed that the tight spandrel connections, built to resist the wind, gave the building a remarkable ability to redistribute loads from severed columns to those that remained intact.

This rearrangement was so efficient, the calculations show, that stresses on columns no more than 20 feet from the hole punched in the tower's face were barely higher than what they were before the impact.

But the fires continued to burn. Black smoke poured from shattered windows on floor after floor, fresh oxygen sucked in from the gaping holes caused by the impacts. In the northeast corner of the south tower's 80th floor, where office furniture had



South Tower

IMPACT 9:02:54 a.m.

COLLAPSE 9:59:04 a.m.

Load supported by the destroyed exterior columns was redistributed to adjacent columns, but it is believed that 1 columns did not exceed their load capacity.

Initially, floors near the impact suffered severe damage across a horizontal span of about 70 feet.

The impact is believed to have disrupted the sprinkler and fire standpipe systems, preventing operation. Even had these systems not been damaged, they would probably have been ineffective, because the initial flash fire would have opened so many sprinkler heads that the systems would have quickly depressurized. Also the fire was so extensive that sprinklers would have been ineffective.

Most intense fires.

A stream of molten material — thought to be aluminum from the plane — flowed down the side of the building.

North Tower

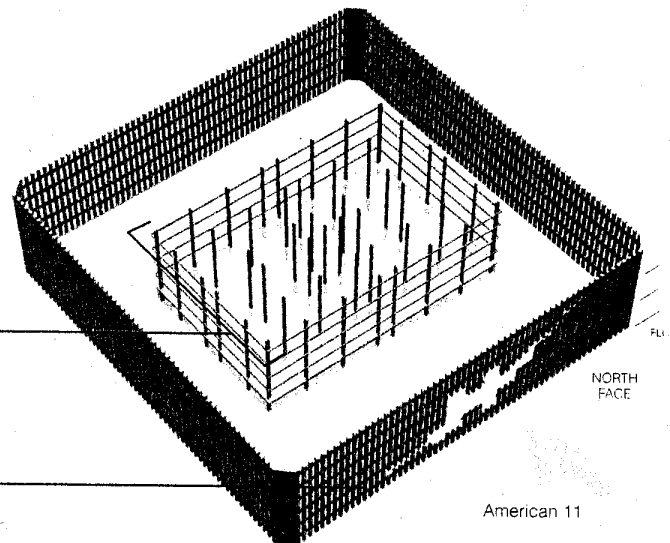
IMPACT 8:46:26 a.m.

COLLAPSE 10:28:31 a.m.

As the plane plowed through the building, it created a cloud of jet fuel that ignited into fireballs, burning an estimated 1,000 to 3,000 gallons of jet fuel. The pressure was sufficient to break windows, but not enough to cause significant structural damage.

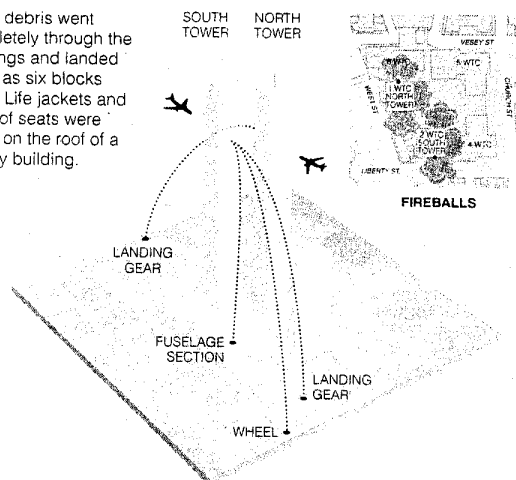
People on the 91st floor described extensive debris in the eastern part of the central core. This suggests a partial collapse of framing in the central core.

Floors supported by the missing sections of exterior walls appear to have partly collapsed across a horizontal span of about 65 feet.



The Impact

Some debris went completely through the buildings and landed as far as six blocks away. Life jackets and parts of seats were found on the roof of a nearby building.



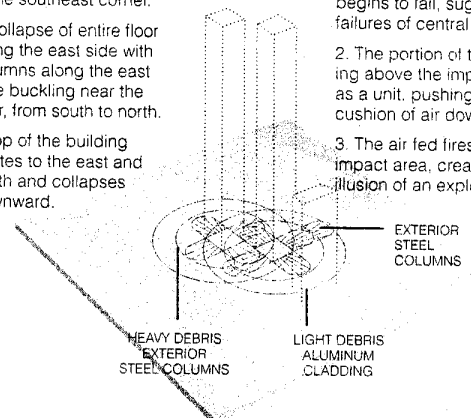
The Collapse

SOUTH TOWER

1. Partial collapse of floor in the southeast corner.
2. Collapse of entire floor along the east side with columns along the east face buckling near the floor, from south to north.
3. Top of the building rotates to the east and south and collapses downward.

NORTH TOWER

1. Television antenna begins to fail, suggesting failures of central column.
2. The portion of the building above the impact fell as a unit, pushing a cushion of air down.
3. The air fed fires in the impact area, creating the illusion of an explosion.



Source: Draft report by the Federal Emergency Management Agency

Baden Copeland, Mika Gröndahl, William McNulty, Sarah Slobin and Archie Tse/The New York Times